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Inverter operation using ASIC EG8010

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INTRODUCTION

With this project we want to verify the possibility of using an inverter system based on microcontroller that, in variable frequency and amplitude conditions, gives optimal results comparable to a normal inverter system, with the difference that this system uses a low-cost microcontroller. Indeed, the purpose is to evaluate the degree of precision that can be achieved by using this integrated solution. The project was divided into 2 phases. The first phase of the project saw the realization of the circuit necessary to carry out tests. For the second phase it is planned to carry out an evaluation of the possible regulation of the frequency and of the voltage acting on the chip by evaluating the best methodology to realize it.

CHAPTER 1

1.1 What is an inverter for short

An inverter is an electronic system able to transform a direct current (DC) into an alternating current (AC), with specific voltage and frequency characteristics. A device of this type can in fact be used in order to feed any electrical circuit or device which necessarily requires an alternating connection. This device is widely used in photovoltaic systems. They produce direct current energy which, in order to be exploited, must necessarily be transformed before being sent to the user or fed into the electricity grid. As you can well understand there are many inverter systems, among the most common we have: inverter square wave, modified sine wave and pure sine wave. The simplest type of inverter consists of an oscillator that drives a transistor, which has the task of generating a square wave opening and closing the circuit. The wave is then applied to a transformer that supplies the required voltage to the output. Today rather than transistors it is preferred to use more efficient devices such as MOSFET, thyristors or IGBTs. The problem, however, lies in the generation of the square wave, which has a number of higher harmonics that can disturb the electrical network, the device can create problems of electromagnetic compatibility. To overcome these problems, the inverters are operated with the PWM system, that is of pulse width modulation. It is understood that the value of the voltage must pass, therefore from a value + V to one -V, in an uninterrupted manner in order to obtain the sinusoidal waveform. The reversal of the project is a single phase full-bridge inverter. It consists of four MOSFET that if opened appropriately can realize what is required. An explanatory diagram is shown below:

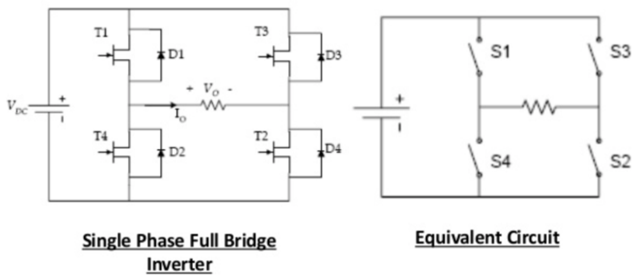

Fig.1 Full bridge Inverter

When the opposite MOSFET (T1-T2, T3-T4) are in conduction on the load, there will be a voltage which, depending on the direction of the current, will be positive (Fig. 2) or negative (Fig.3).

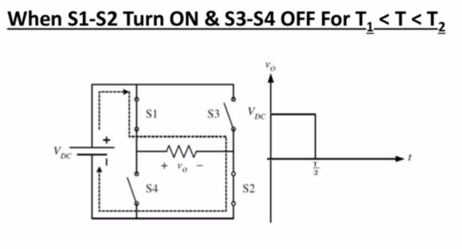

Fig. 2 Operating diagram of inverter, positive phase

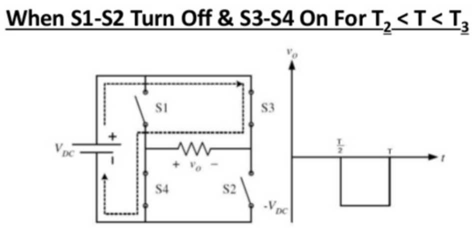

Fig. 3 Operating diagram of inverter, negative phase

This opening and closing will be done by the components quickly in order to have continuity in the waveform. Thus, the operation of an inverter can be summarized.

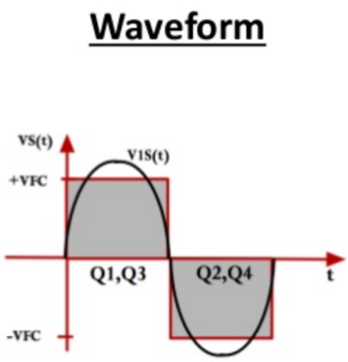

Fig. 4 Wave form

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1.2 Analisys of the component

As said, the first phase of the project is based on the realization of the circuit on which the regulation will be carried out. One of the main components of this circuit is characterized by the EGS002 driver board. It is characterized by a control chip and two driver chips. The driver board can be used to provide protection against voltage, current and temperature, as these functions are integrated into the driver due to the architecture of the card. The AC 50/60 Hz configuration is also available, as is the soft start and dead time mode. Finally, it is possible to connect to this device an LCD screen that allows you to view the most important parameters such as voltage, current frequency and temperature.

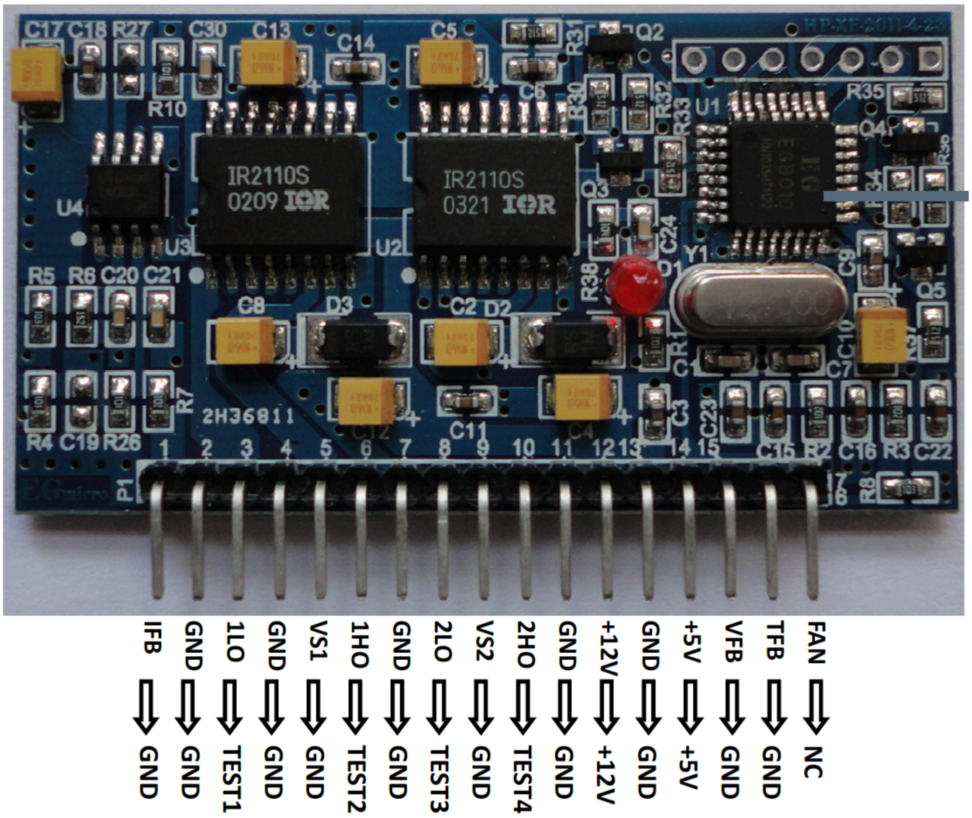


Fig. 5 Photo board EGS002

The heart of this card lies in the chip installed on it called EG8010. It represents a digital inverter sine wave, which allows to totally control the dead time and applied to Full Bridge DC-AC power conversion system, or even to a single-stage DC-AC low-voltage transformer. It is therefore appropriate to elaborate on the specifications of this chip.

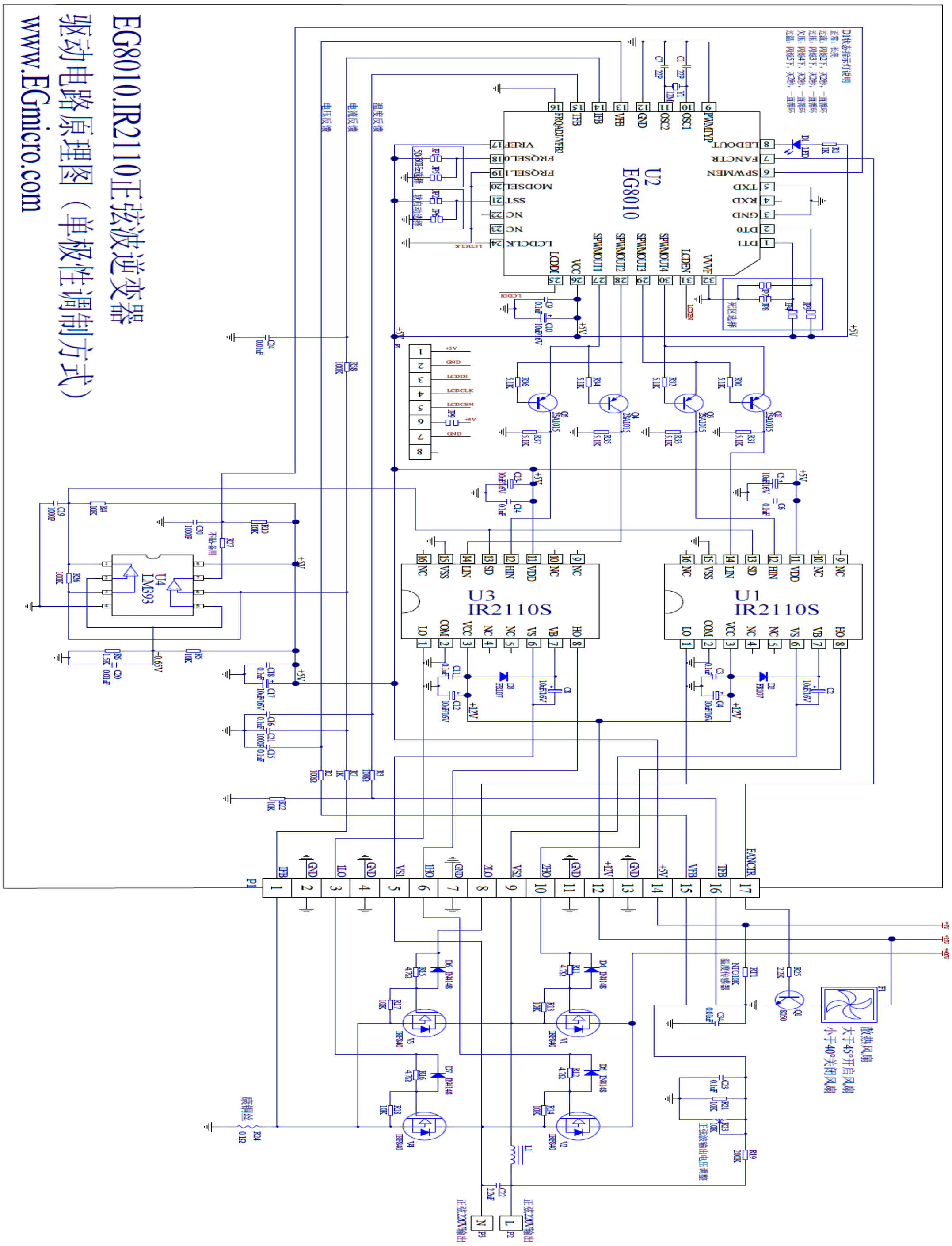


Fig. 6 EGS002 Sinusoid Inverter Driver Board Schematic

1.3 CHARACTERISTICS OF THE EG8010 CHIP

As already mentioned, it represents the heart of the EGS002 board. In fact, this chip allows to obtain the pure sine wave at 50/60 Hz with high precision and low harmonic distortion. It is also an external 12MHz crystal oscillator that allows you to adjust the system clock. Lastly there is a sinusoidal SPWM generator. We report below the block diagram and the electrical characteristics of the chip.

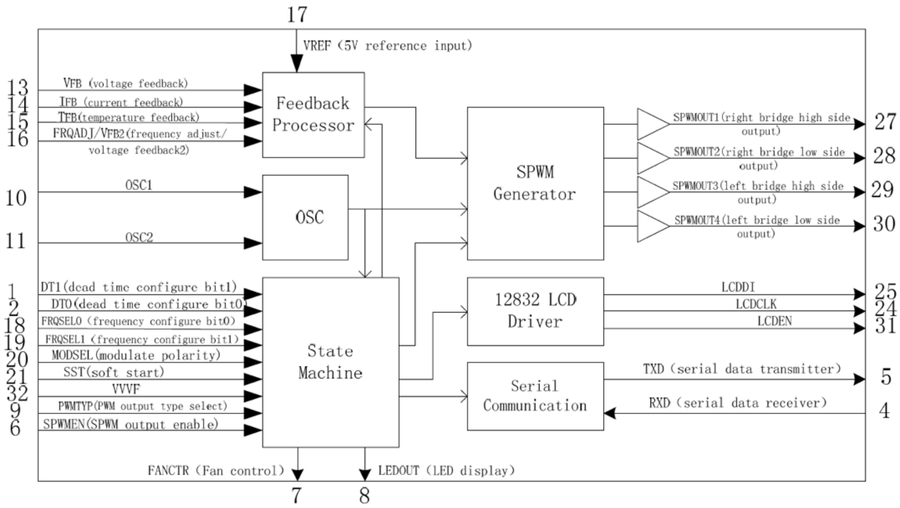


Fig. 7 Block diagram chip EG8010

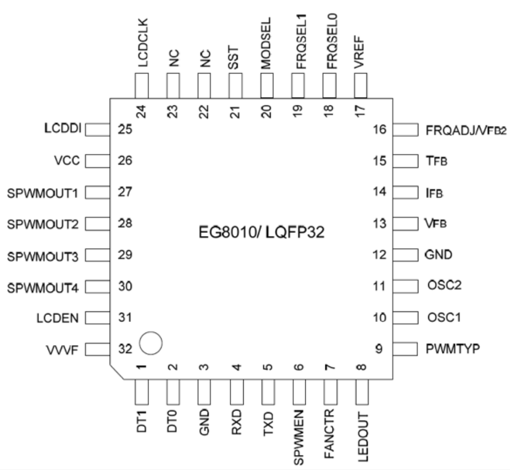


Fig. 8 Pin map of the chip EG8010

With unipolar modulation operation, only one of the two bridges (SPWMOUT3 and SPWMOUT4) will be used for the output modulated in SPWM, the other bridge will be used instead for the fundamental output (SPWMOUT1, SPWMOUT2). From the circuit point of view there will be an inductor and a capacitor, to create an LC filter, connected to the output port of the SPWM and there will also be a voltage feedback circuit connected to the output of the inductor.

1.4 Feedback on AC output voltage

With this type of operation, the EG8010 chip can measure the AC output voltage of the inverter via the appropriate VFB pin (13), through the feedback process itself. With this type of modulation, it is therefore possible to calculate the error between the measured peak voltage and the reference voltage (3V) and adjust the output voltage accordingly. Therefore, when the output voltage increases, the relative pin voltage will increase. So, in order to achieve stabilization of the voltage, the circuit will perform the error calculation and will adjust the division factor of the interval by decreasing the voltage in order to stabilize it.
This process can be schematised as follows:

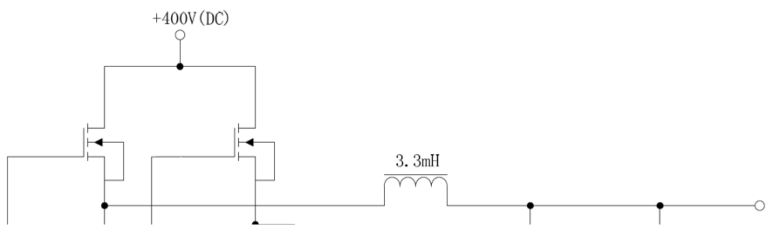


Fig. 10 Control model

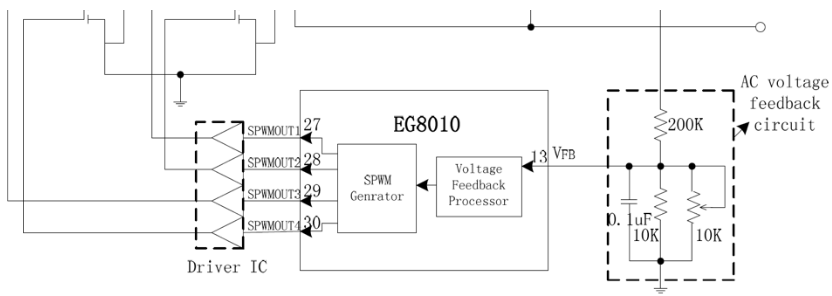
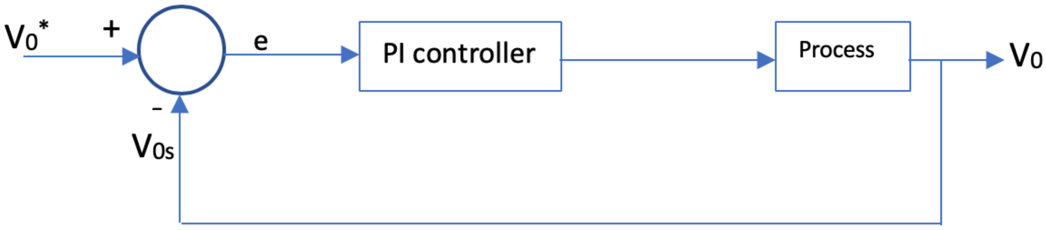
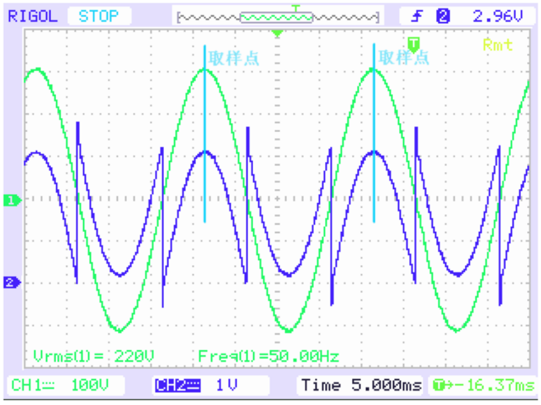


Fig. 9 Voltage control system

On the contrary when the voltage on this pin decreases, the chip will increase the output voltage. This adjustment can be seen in the following figure.



It uses a type of sampling at the peak point. In this way if the output voltage should be deviated, for example due to load or input voltage variation, the EG8010 can recover to expected output voltage in one to three cycle of the generated alternate voltage.



CH1： 220V/50Hz AC output wave CH1： VFB voltage feedback wave

Fig. 11 Wave form

If, on the other hand, the bipolar modulation is used, the feedback will consist in measuring the output voltage via the left bridge and the VFB2 pin. For this type of circuit, the error is measured between the peak differential voltage measured by the differential feedback which has two channels and always the maximum voltage reference (3V), thus regulating the output voltage. This calculation of the error allows the circuit to adjust the division factor of the interval to obtain the stabilization of the voltage.

In the event that the voltage can be too high or low when the load is powered, the chip has an integrated overvoltage and voltage protection system. The values set for these two cases are:

• 3.15V with 300mS delay, for overvoltage protection;

• 2.75 V with 3S delay, for under-voltage protection.

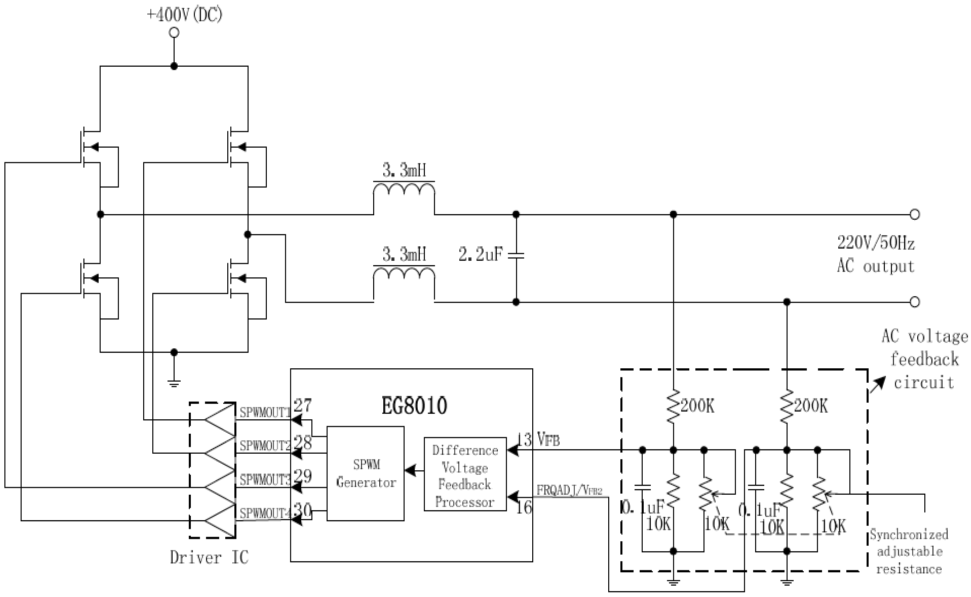


Fig. 12 Voltage control system in bipolar mode

If both situations occur during operation, the system automatically, depending on the settings of the PWMTYP, will send a shutdown pulse to the relative pins to turn off the MOSFET, reducing the voltage to 0. After 8 seconds from the activation of the protections, the chip will send an ignition pulse for 100mS, performing a new test on the output voltage. This process can be repeated 5 times in cycles of 8 seconds, whenever the problem does not resolve. If the problem persists, the SPWM will be turned off, and in order to start the system again it will have to be restarted in a forced way.

If instead of eliminating the problem, then when the system will work for more than one minute consecutively, the overvoltage and undervoltage counter will zero, and will restart only if the problem should arise again. This control system is called Feedback on the AC output voltage. In addition to this voltage control system, there is also the feedback control system on the AC output current.

1.5 Feedback on AC output current

As for the voltage feedback, also for that of the current there will be a pin of the dedicated chip EG8010, in order to be able to evaluate overcurrent phenomena that could destroy the MOSFET. In fact, in the presence of overcurrent, the pin IFB (14) will compare the voltage value of the circuit with the reference voltage value of 0.5V in an overcurrent detection time equal to 600ms. If the current is higher than the inverter current, the EG8010 chip will set the SPWMOUT pins so that the MOSFET is switched off, in order to reduce the voltage to 0 depending on the setting of pin 9.

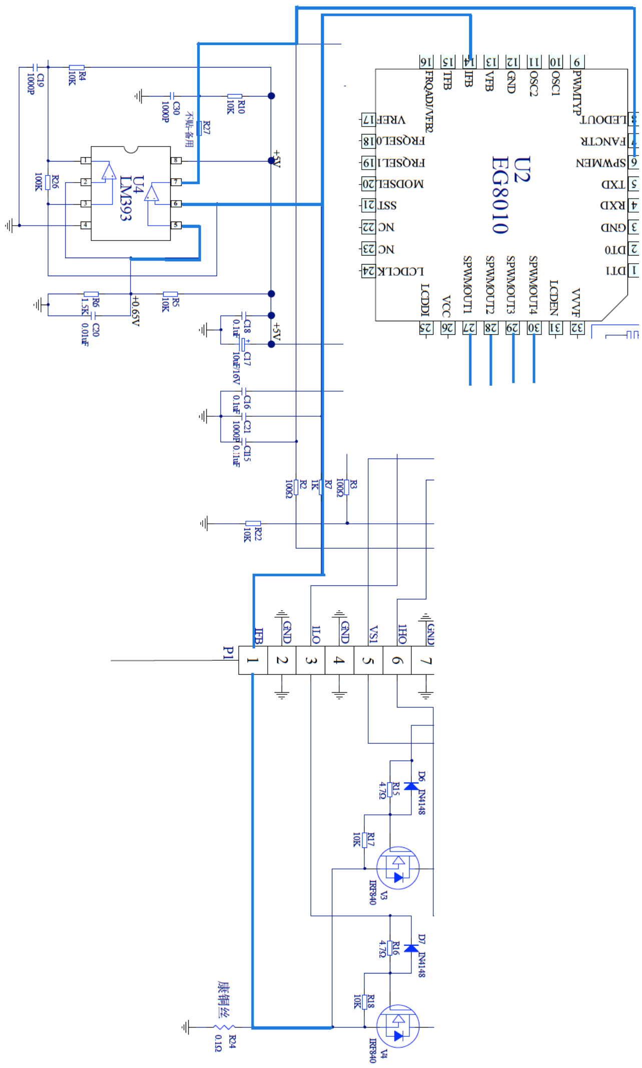


Fig. 13 Current control system

In this way it is possible to protect both the MOSFET and the load. As with the overvoltage detection system, here too there are activation and deactivation cycles if the disturbance that led to the shutdown of the system for the first time should still be present. The timing is different, in fact 16 seconds after deactivating the MOSFET the chip will turn it on again for 100ms in order to determine the load current. If the problem persists, the MOSFET will be deactivated again, repeating this procedure for a maximum of 5 cycles, beyond which the SPWM output will be deactivated. In order to make the system work correctly, a forced restart will be necessary, with times that could lengthen if the starting current should be high, since it will be necessary to connect the IFB pin to ground. If, on the other hand, the chip detects correct operation for at least an entire minute, then it will reset the counter. In addition to these functions there is also a temperature feedback sensor.

1.6 Temperature Feedback

The pin assigned to this function is the TFB, is pin 15. It communicates with the external system to the board, characterized by the NTC probe, thanks to which, together with the intermediate circuit between the pin and the sensor, it returns the temperature feedback in the LCD screen, because when the NTC resistor changes, the voltage will change, thus determining the temperature value. Here too there will be cycles to protect the MOSFET. However, since in our case we will not use this detector, the pin must necessarily be connected to the ground.

1.7 Different types of PWM output settings

The setting is guaranteed by the PWMTYP pin which allows to select the type of output. In fact if the pin is set to "0" the positive PWM output is applied to the field where the dead level is low, like the IR2110 driver, this is shown in the following diagrams.

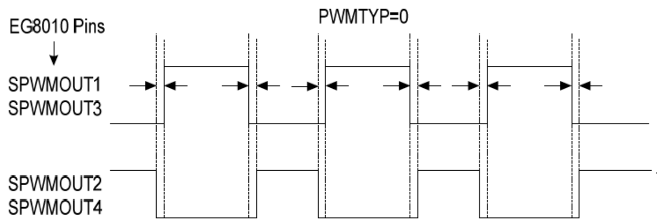


Fig. 14 Positive output PWM EG8010

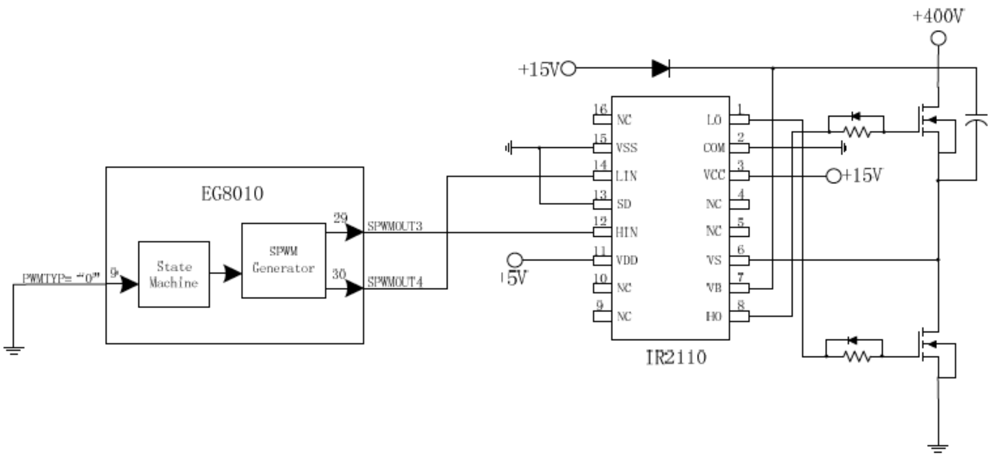


Fig. 15 EG8010 Driver PWM positivo IR2110

If the PWMTYP is set by "1", the PWM output this time negative is applied to the field where the dead level is high.

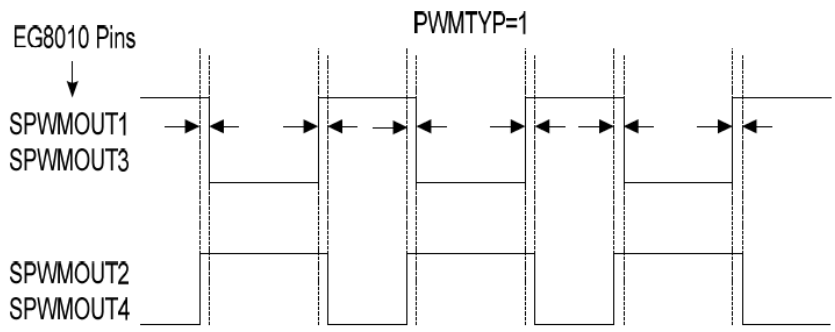


Fig. 16 Negative PWM output

Another function that is necessarily important for the functioning of the MOSFET is the regulation of dead time. This is ensured by the EG8010 chip, which allows 4 types of dark time settings. "00" = 300nS. "01" = 500nS. "10" = 1uS. "11" = 1.5uS. If the dead time is not sufficient, the MOSFET will be damaged by the conduction. If it should be too long, the MOSFET will overheat and waveform distortion will occur. The four types of regulation are shown below:

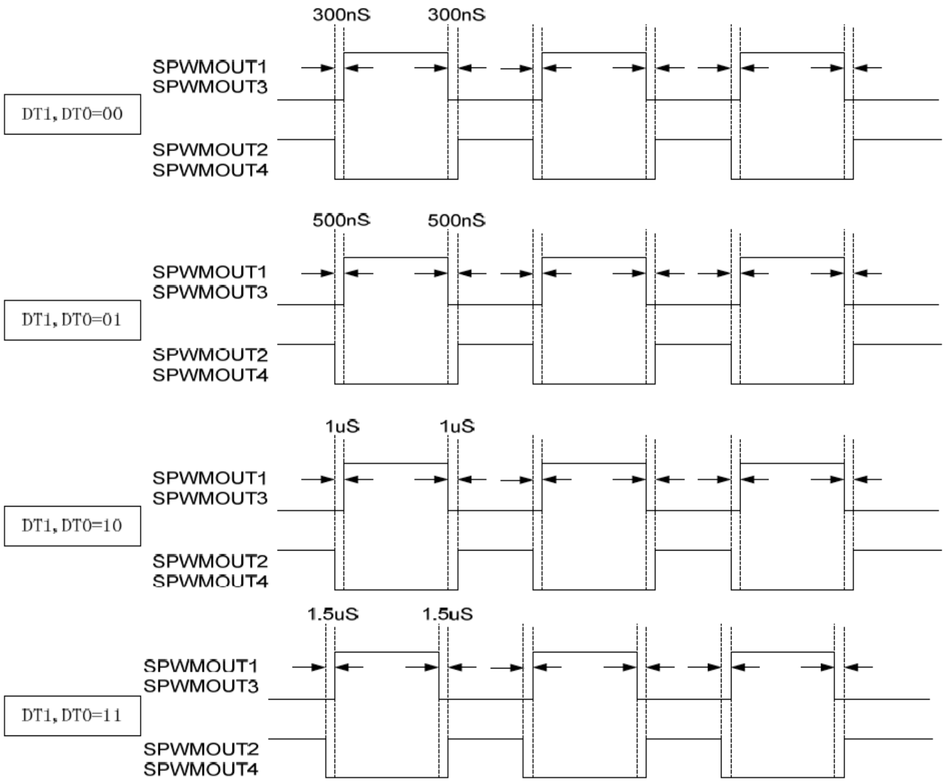


Fig. 17 Dead time setting EG8010

Another function of the EG8010 chip is that used for frequency regulation.

1.8 Frequency setting

As already mentioned, this board allows operation in two frequency modes, the one with adjustable frequency and the constant one. With the first adjustment, the chip uses only the unipolar modulation in which the MODSEL pin (20) must be connected to a low level. In this way the pins FRQSEL1 and FRQSEL0 will set the frequency mode, at 50 Hz or 60 Hz with a coding of type "00" for the first and "01" for the second. In the case of an adjustable frequency, the frequency ranges will be 0-100 Hz and 0-400Hz, with a coding of "10" and "11".

This adjustment takes place via the FRQADJ pin which detects the voltage value that can vary from 0-5 V according to the frequencies indicated above. The frequency regulating circuit diagram is shown below.

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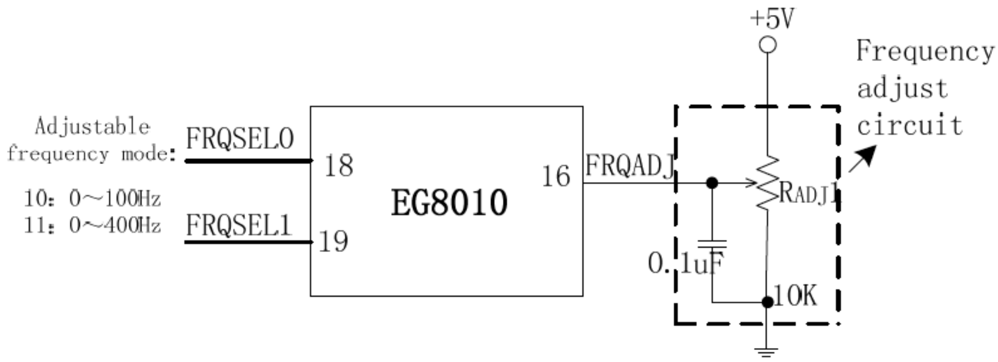


Fig. 18 Frequency regulation circuit

This adjustment function is also supported by the VVVF pin, which can be used in the single-phase frequency transformer system. In fact, if the VVVF operation is set to "1" the constant V / f ratio can be maintained by acting on the voltage as the output frequency varies. On the other hand, when VVVF is at "0", the output voltage is not changed even if the voltage is changed.

As we have seen in these feedback systems, what is regulated by the protection of the MOSFET are the SPWM pins, which, depending on the parameter they monitor, can switch off the MOSFET or not. For this reason, it was necessary to deepen the part concerning the OUTPUT PMW.

Chapter 2

2.1. Realization of the circuit

After a careful analysis of the EGS002 card, we proceeded to create the circuit to which the card should be connected, in order then to be able to do all the necessary tests for this purpose. We proceeded to create the circuit on a small plate that made it possible to make all the necessary connections. The diagram below identifies the pins of the board and the related external circuit to which the load is then connected.

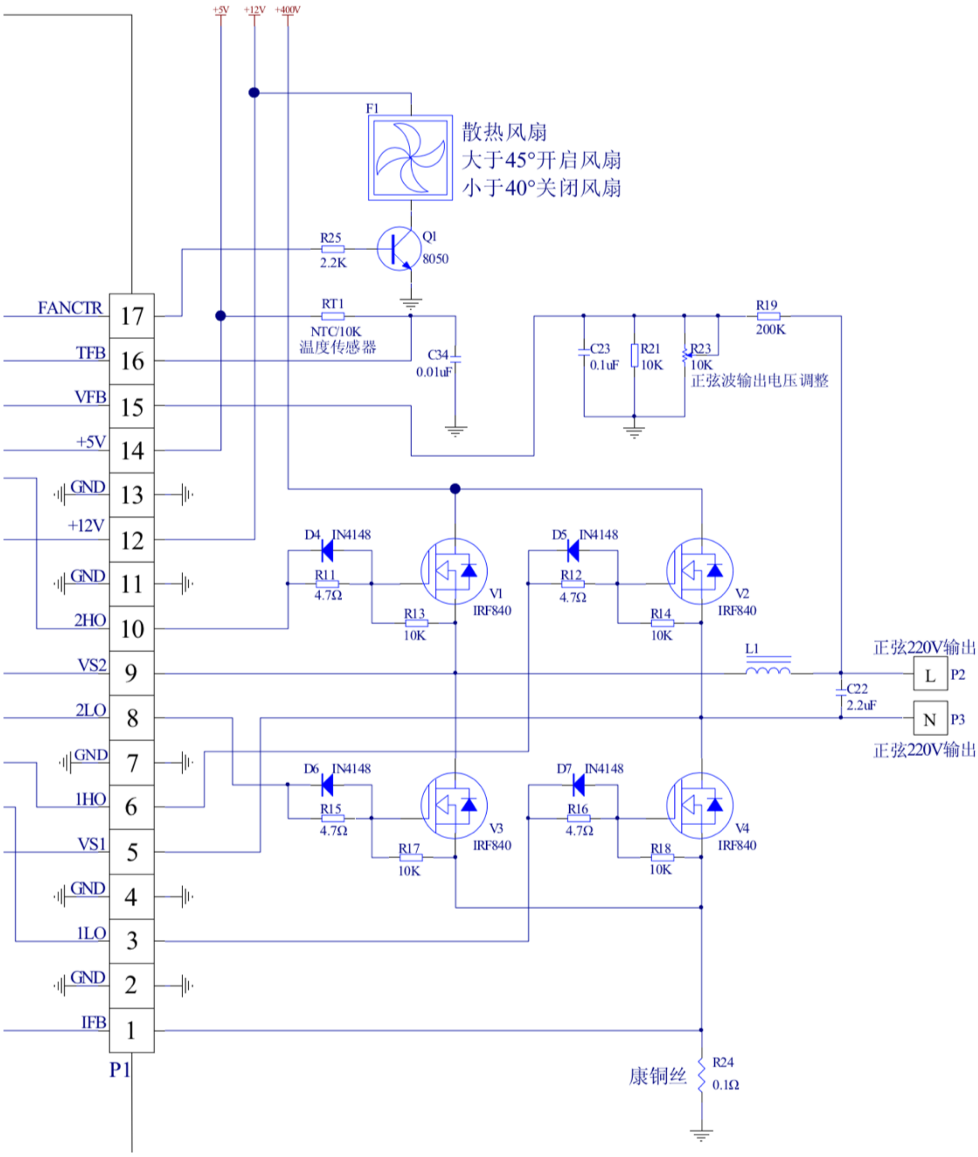


Fig. 19 Circuit taken from the datasheet

As already mentioned above, the temperature detection system as well as the ventilation system will not be used. In a first phase it was decided to follow the diagram indicated in the datasheet and shown here, but making some changes. In fact, an inductance has been used (indicated in the diagram with L1) whose value is about 3mH and a capacity (indicated in the diagram with C22) whose value has been changed to 3μF ±5%. The whole was then subsequently connected to the power supply. As power supports, 2 power supplies of the MAISHENG MS-30100 were used, to realize the 400V power supply indicated in the diagram, but replaced by us with a 64V power supply (regulated at a value of 32 V each) provided by the two power supply. The choice to power the 64 V circuit instead of 400 V was made so that you could work in the laboratory in complete safety. For the 12 / 15V and 5V a different power supply was used, in fact, a system was created specifically that was able to give two different outputs in voltage. The images of which are shown below.

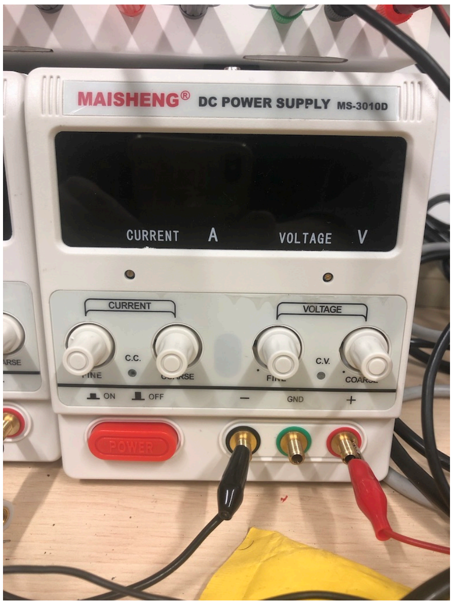


Fig. 20 Power Suplly for 32V

Fig.21 Power supply 12 and 5 V

The complete circuit, whose images are shown below, is therefore connected to the oscilloscope (model DL1520 of the YOKOGAWA) in order to be able to evaluate the output waveforms at the points where the load is connected. As a load a simple 1 kΩ resistance was chosen.

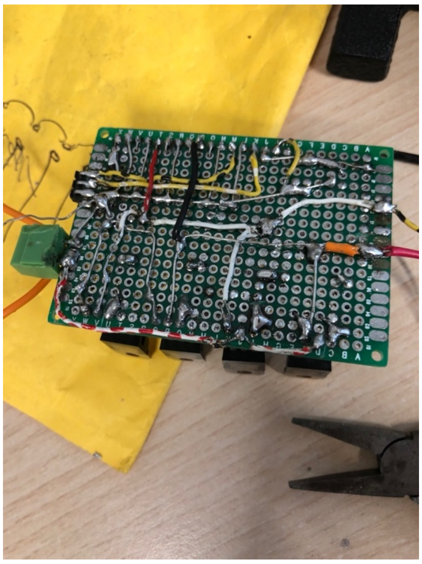


Fig. 22 Back of the breadboard and the circuit boards

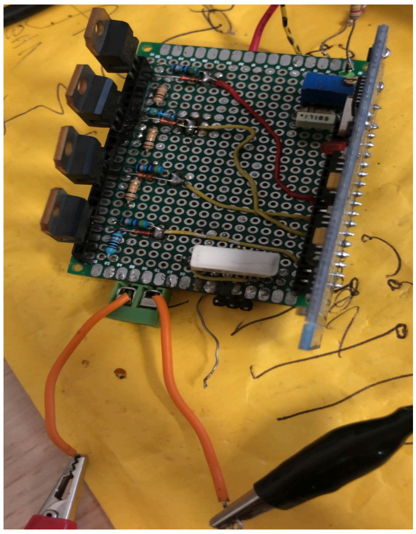


Fig. 23 Top view of the board connection circuit

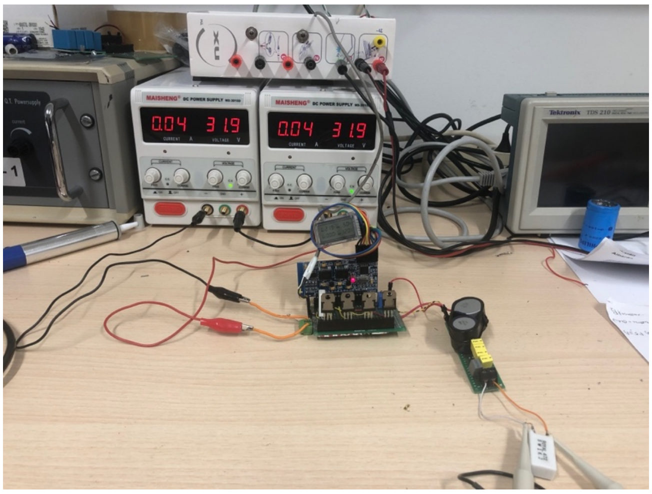


Fig. 24 Top view of the board connection circuit

A first problem that arises is related to the correct operation of the board that actually detects, through a flashing, the presence of overcurrent. To overcome this problem as first solutions, different load options have been evaluated. However, this solution did not lead to the elimination of the problem. Subsequently, an adjustment was carried out using the potentiometer which, however, also in this case did not lead to significant improvements in the system. Subsequently the sensitivity resistance R19 was changed, in order to be able to find the correct combination that allowed the card to operate continuously. After numerous tests, the correct combination of 1 kΩ load, the sensitivity resistance R19 from the value and 150 kΩ was reached. Therefore the new scheme will be the following:

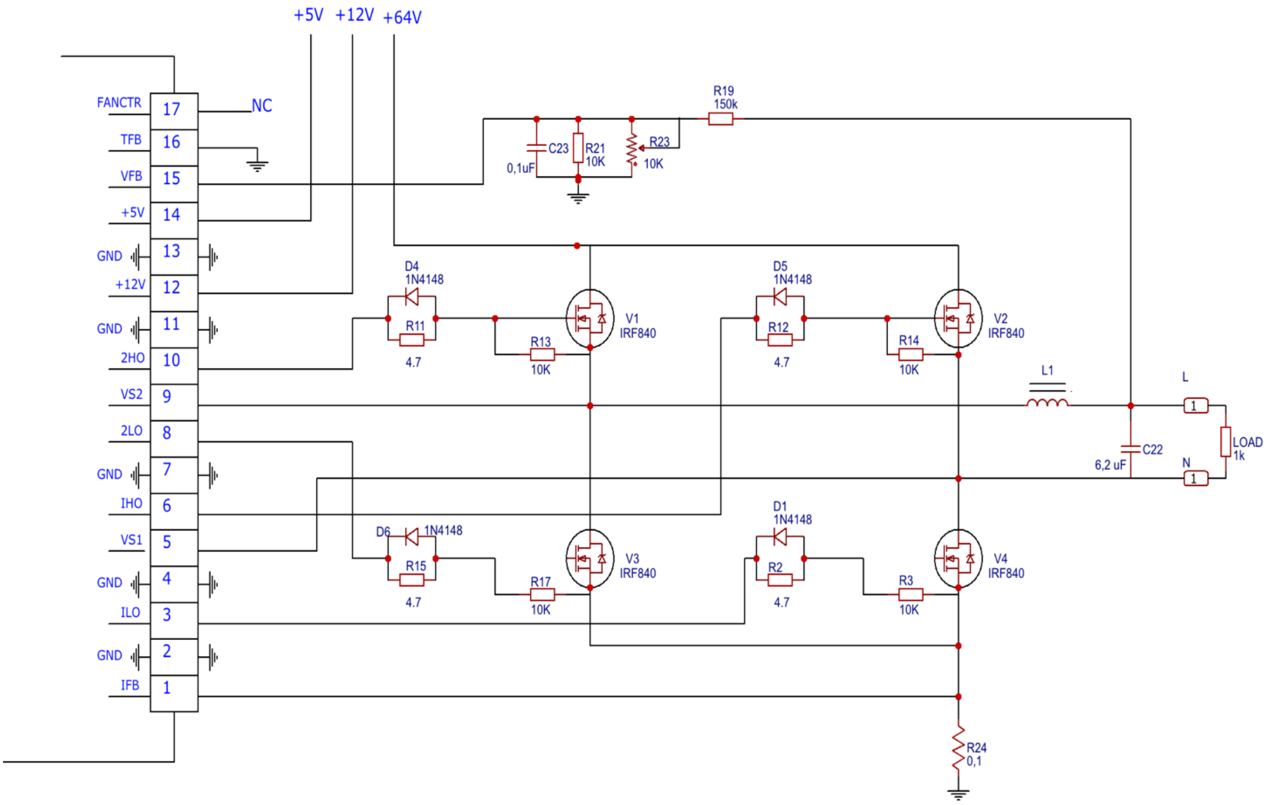


Fig.25 The new connection scheme

Despite the constant operation of the board, which no longer showed the flashing LED, the first results obtained were not satisfactory. In fact, by connecting the probes to the end of the load it was noticed that these waveforms were particularly disturbed, as can be clearly seen from Figure 16.

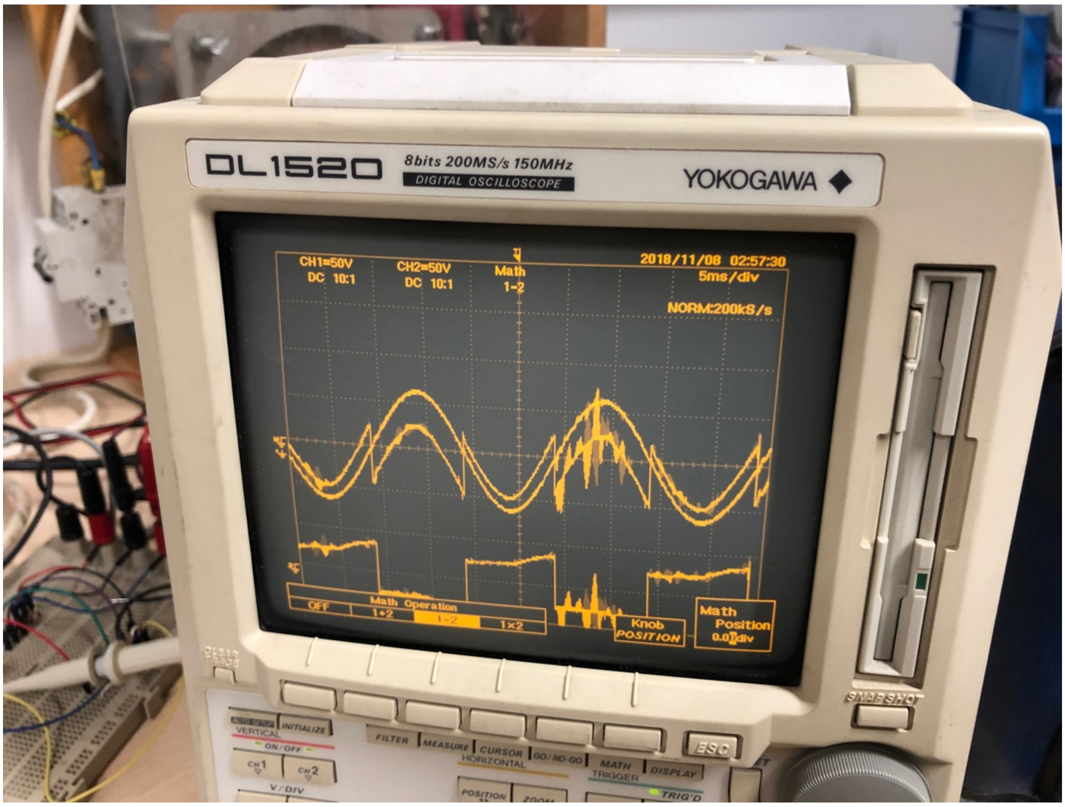


Fig. 26 Disturbed waveform

This waveform was obtained as the difference between the two signals detected at the ends of the load. The resultant is therefore a sine wave.

In addition to this problem it has been noted that, whatever the position of the potentiometer, in the diagram with the symbol R23, the amplitude of the waveform did not undergo any variation. Therefore, further changes to the scheme were made. These changes consist of replacing the LC filter components using:

• 2 inductances, one of 0.54 mH and one of 0.71mH;

• 6 total capacities connected in parallel for a total value of 6.2 μF including 4 capacities of 4 μF (yellow in the figure) and 1 capacity of 2.2 μF (gray in the figure).

With regard to the lack of sensitivity of the potentiometer, the resistance of 10KΩ, indicated with the name R21 in the diagram, put in parallel with the potentiometer and the C23 capacity, has been eliminated. In this way the sensitivity of the potentiometer has been restored. Therefore, the new circuit will be the following:

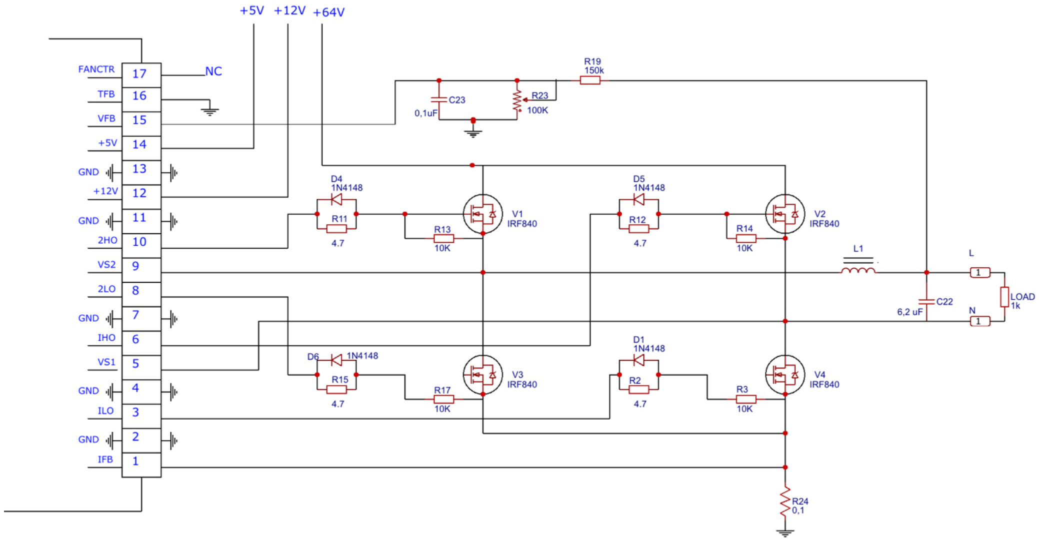


Fig.27 New circuite scheme

Following these modifications, the test and the relative acquisition of the signal were carried out again, thus achieving much better results. As you can see from the images, the value of the voltage, thanks to the potentiometer this time changes.

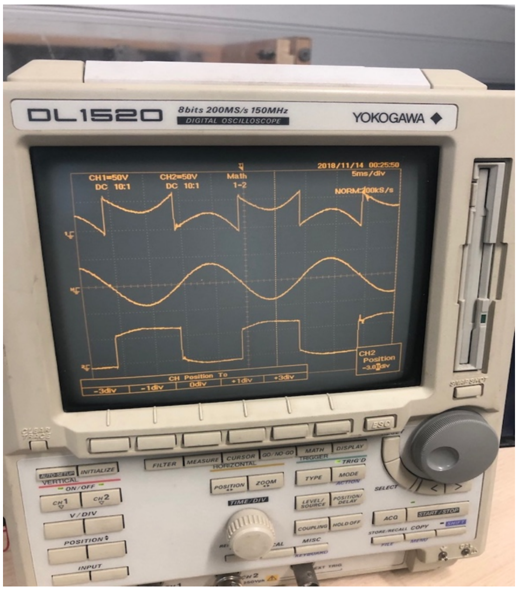


Fig.28 Waveform before adjusting the potentiometer.

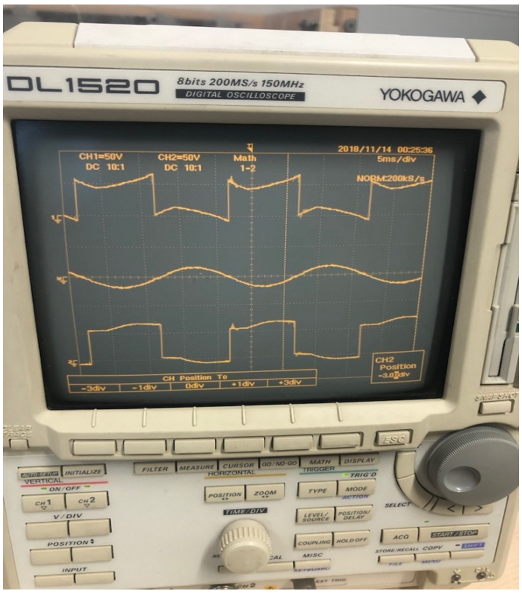


Fig.29 Waveform after adjusting the potentiometer.

The second phase of the project concerns the regulation of the frequency and of the effective value of the voltage by exploiting the pins of the integrate circuite ASIC of the board.

Chapter 3

3.1.Regulation of the frequency

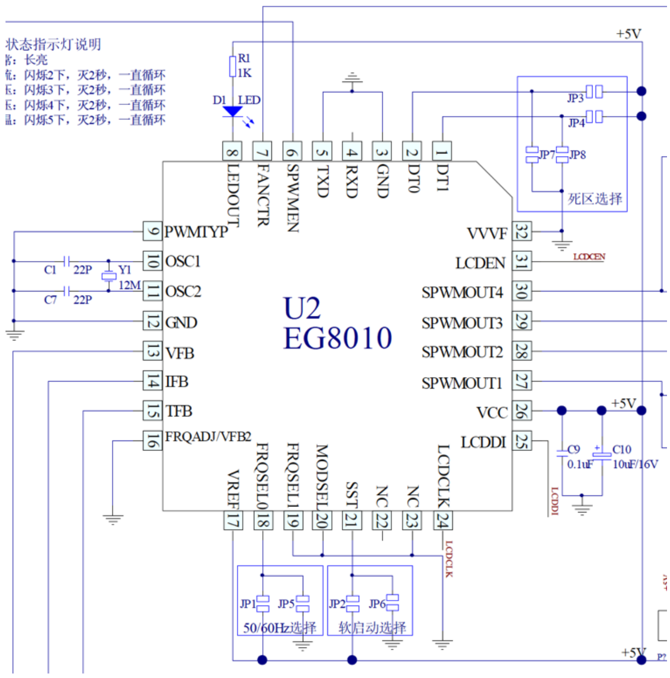


Fig.30 Zoom of the chip

Next phase of the project involves the verification of many possibility of frequency regulation. To do this it was necessary to carry out a careful analysis of the datasheet of the card, in order to be able to identify which pins were dedicated to this task and in what modality this regulation could be performed. First of all, the pin assigned to perform this function has been identified, which is indicated in the card as n° 16, FRQADJ / VFB2. It was therefore necessary to desolder the pin from the card in order to make it accessible, since, to carry out this adjustment, it is necessary to create an external mini circuit that allows to carry out the required regulation. This circuit, shown below in fig. 31 and 32, provides a potentiometer whose central pin is directly connected to

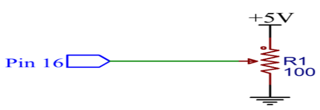


Fig. 32 Connection scheme of pin

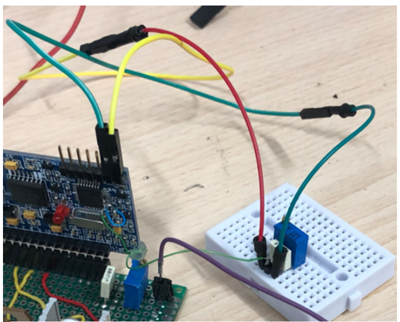


Fig. 31 Realization of the frequency regulator connection

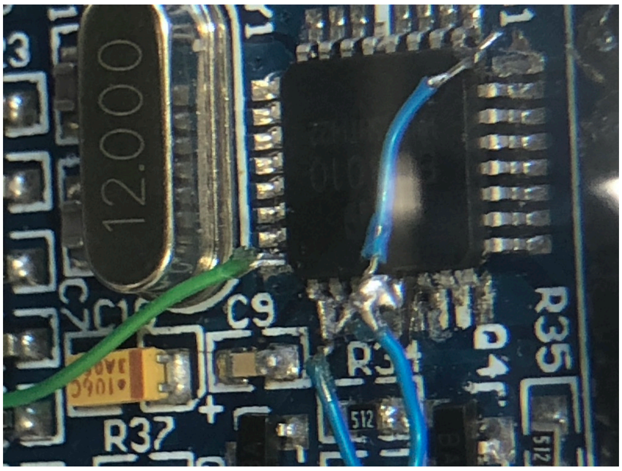
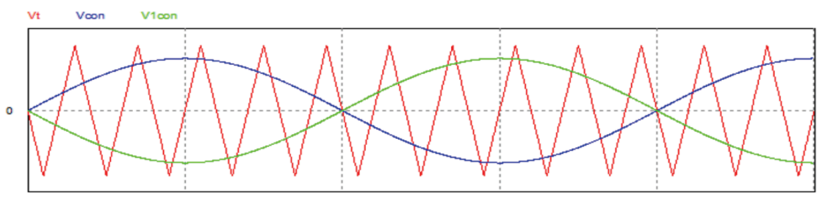


Fig. 33 Enlargement of the connections made on the card

the pin n° 16, while the other two terminals must be connected one to +5 V power supply and the other to the circuit ground. Power and ground connections were made using the connectors on the dedicated display board, which was disconnected for the occasion.

In addition to this modification it was necessary to modify the pins 19 and 32. In fact, in order to make this adjustment, these pins must be connected to 5V. In order to simplify this connection, it is preferred to connect the three pins indicated above to pin 17, which is directly connected to 5V. Since the configuration chosen for this type of board is the unipolar one, the changes mentioned above are those necessary for this type of modulation. This modulation, as already mentioned, is used to create a sinusoid that is closer to the perfect one, minimizing the harmonic content. This modulation involves the use of variable rectangular pulses, but always with amplitude ranging from 0 to V + (or vice versa).



Larger pulses are located near the maximum of the sine wave while they narrow when approaching the minimum. On the side of the power group will be present of the switches, characteristic of full-bridg that are driven by two clock signals that are generated by appropriate comparators. which have the task of comparing the periodic triangular voltage, (Vt), which takes its name carrier, of constant amplitude, with two other sinusoidal control voltages (Vcon and V1con = -Vcon) and thus generating the necessary commands to the static switches on the basis of the comparisons that are made during operation.

3.2.Frequency test

Realized what was necessary, proceeded to connect the circuit, thus modified, to the power supply, connecting the probes to the load. Everything was always powered at 64V, 12 V and 5V approximately through the same power supplies used in the first phase. The LC circuit remained the same. After the connection, after a few seconds that the card needed in order to be able to have a constant operation, the following waveforms were obtained, which are shown below:

Fig. 34 Waveforms after connection of the frequency regulation circuit

These waveforms again give the sinusoidal waveform to the load. The purpose of this further test is to evaluate whether it is possible to carry out the variation of the frequency by means of the external circuit just completed. In fact, through the potentiometer you should be able to adjust the frequency. Unfortunately, following this experiment it was found that frequency regulation is not feasible. Subsequently, however, the card was replaced in order to assess whether this problem was related to a malfunction of the EG8010 chip. So, after having re-set the necessary connections and then re-soldered the pins of the chip again, the whole thing was connected again. With the new board it seems possible this time to adjust the frequency, probably following the numerous tests that had been done previously the chip will be damaged. Below are the images of the successful frequency adjustment.

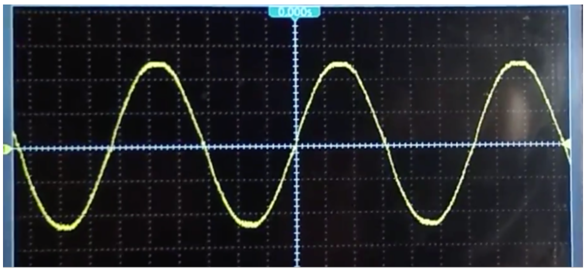


Fig. 35 Waveform at 20Hz

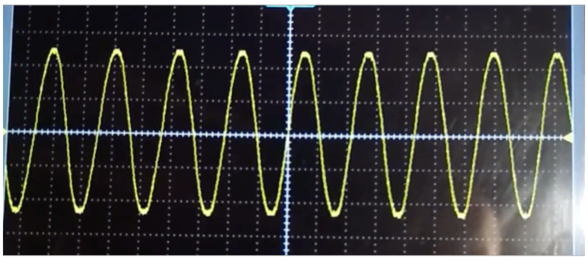


Fig. 36 Waveform at 56Hz

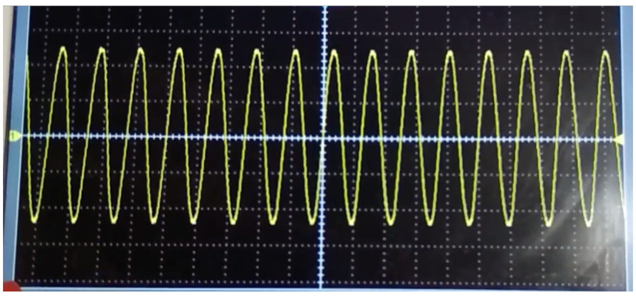


Fig. 37 Waveform at 69Hz

A quantity that can be varied with better margins is the voltage in the module, as can be seen from the images shown below.

Fig. 38 Waveform after voltage regulation

Further tests have been done. One of these was to increase up to 80V about the voltage value by evaluating the relative waveforms again. This increase was achieved thanks to an additional power supply that connected in series to the others already present allowed to increase the voltage value up to 80 V.

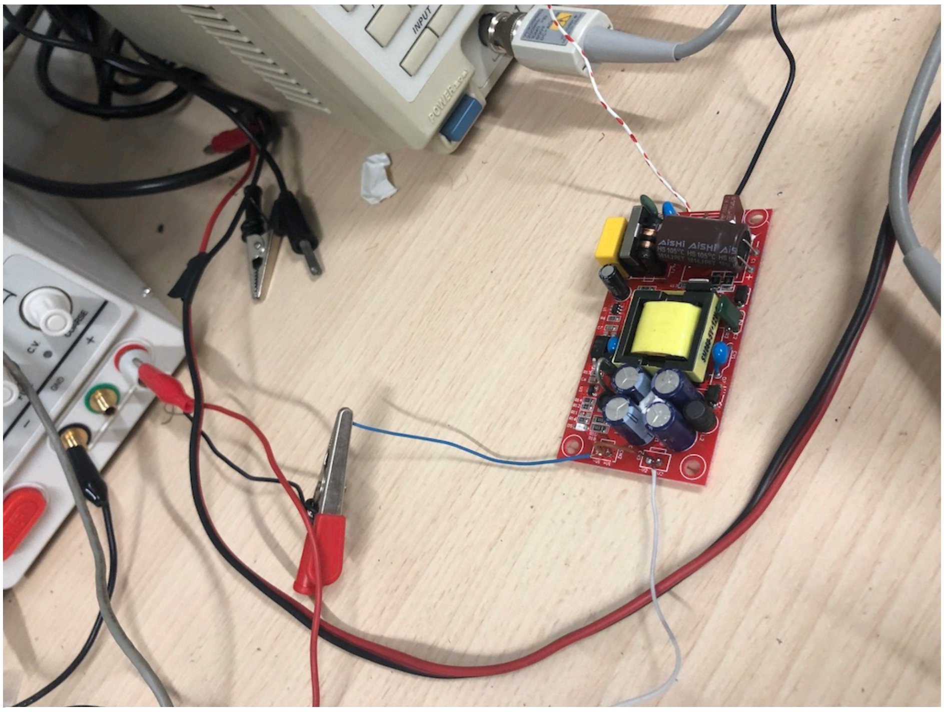


Fig. 39 The added power supply

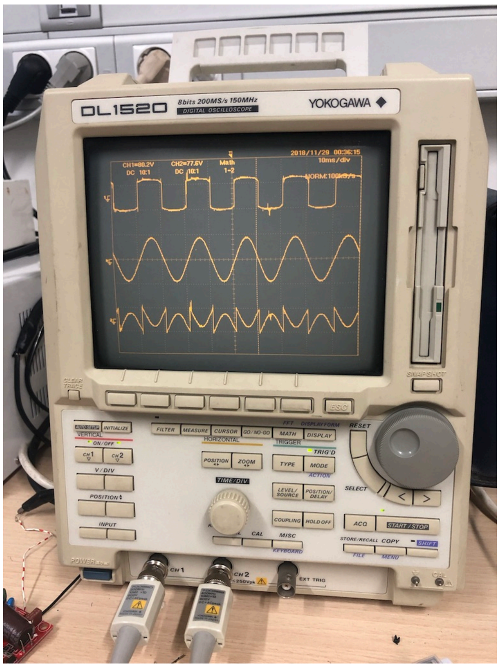


Fig. 40 Waveform with the board without frequency regulationFig. 41 Waveform used

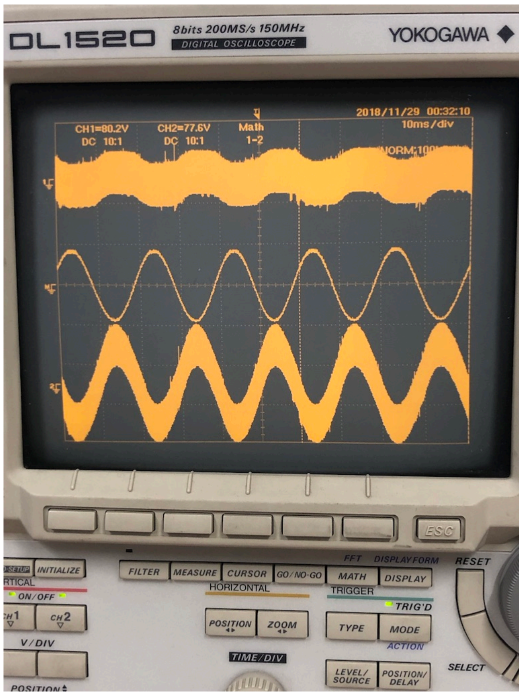
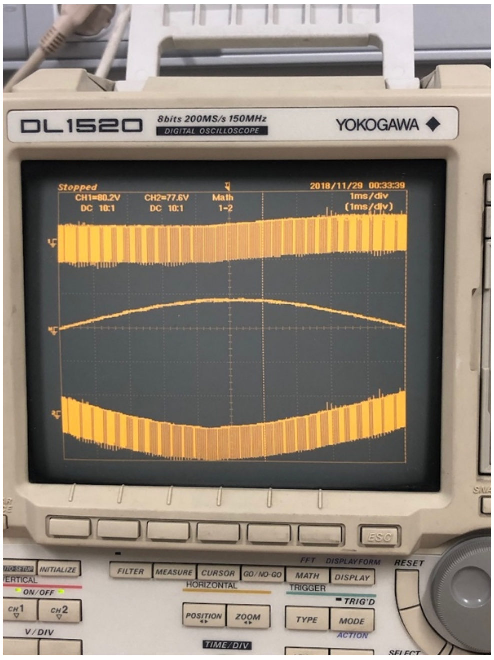


Fig. 42 Waveform after connecting the frequency control circuit



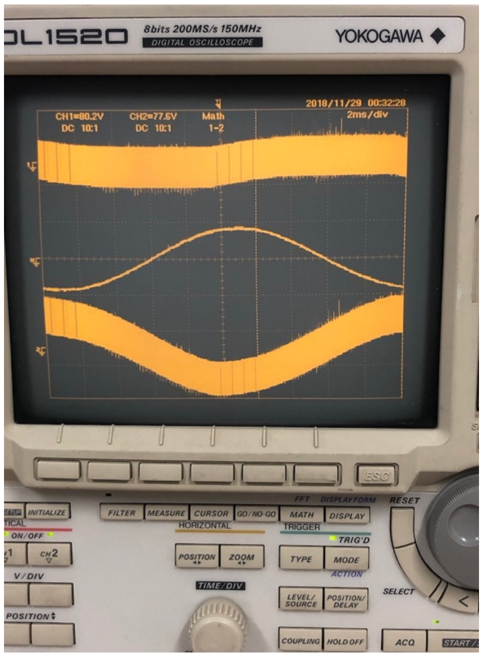


Fig. 43 Zoom of the Waveform with The unipolar modulation

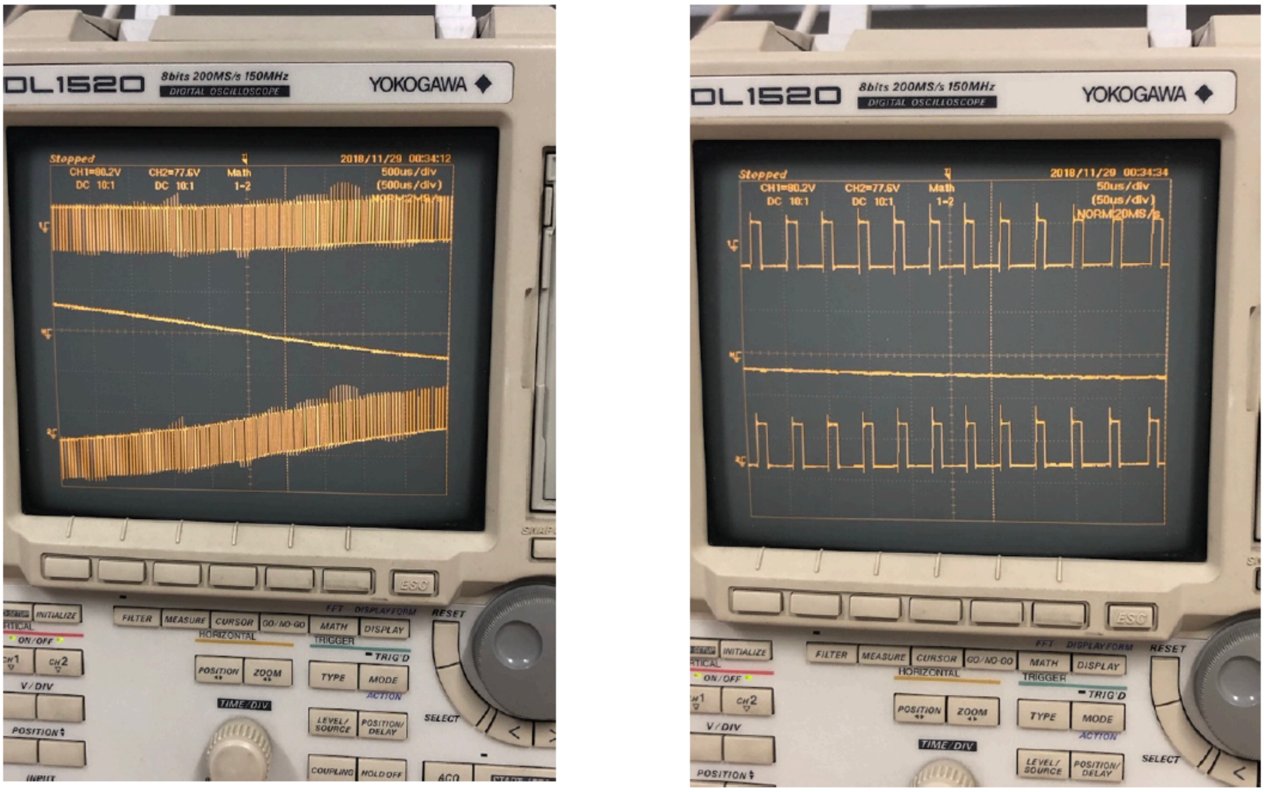


Fig. 44 Unipolar modulation, more detailed view

With these images we can clearly see how the rectangular pulsation, typical of unipolar modulation, varies. In fact, we see how the larger impulses are close to the maximum waveforms while they are tight when approaching the minimum.

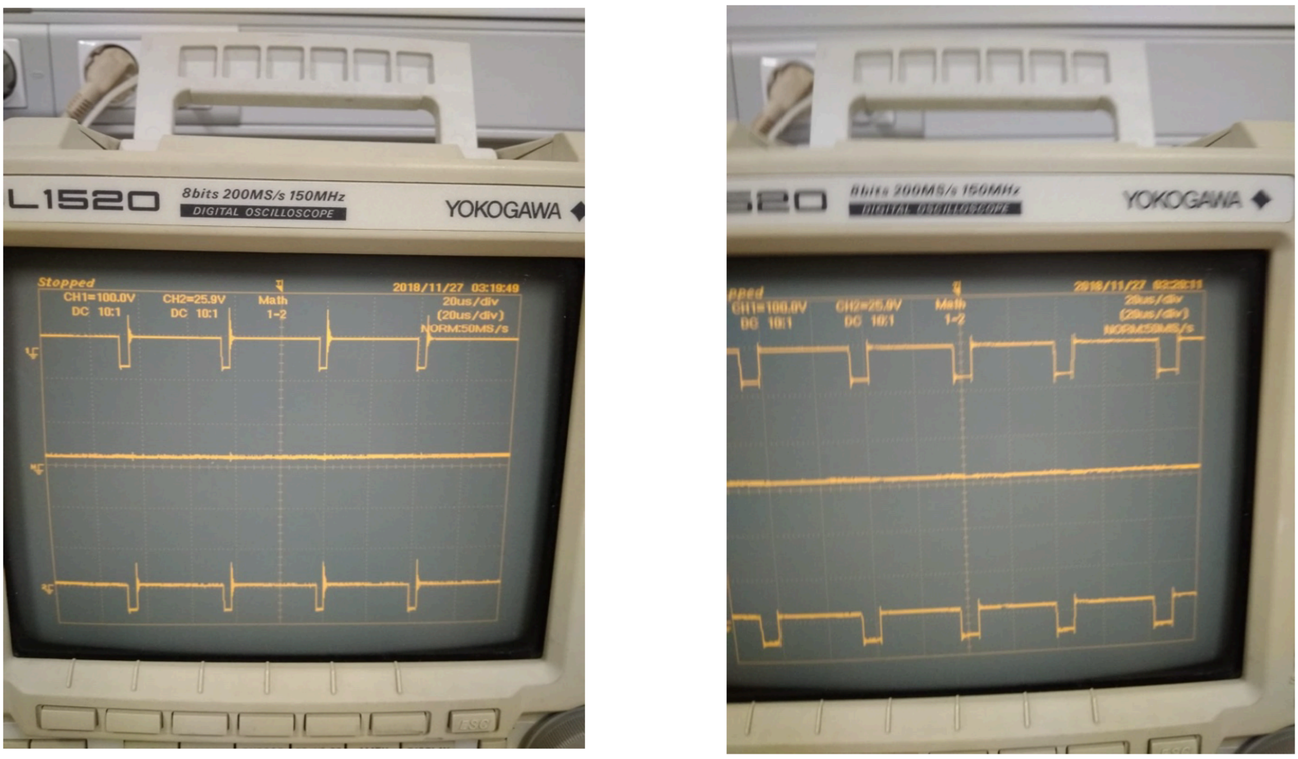


Fig. 45 Unipolar modulation, more detailed view

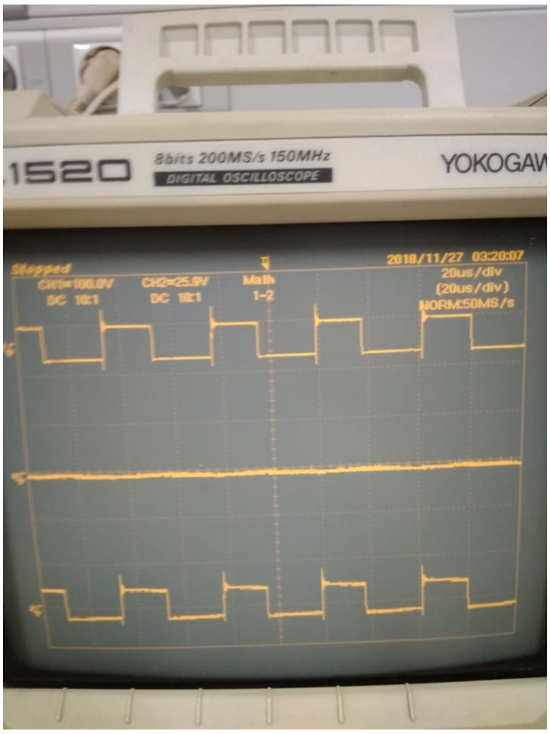


Fig. 46 Unipolar modulation, more detailed view

In order to be able to also test dead time operation, its settings have been changed. To do this, the pin of the card indicated by the letter JP3 was short-circuited instead of JP7. In this way, thanks to the JP3 and JP8 pins, the dead time has gone from a value of 300ns to one of 500ns, as can be seen from the test done on the MOSFET shown below.

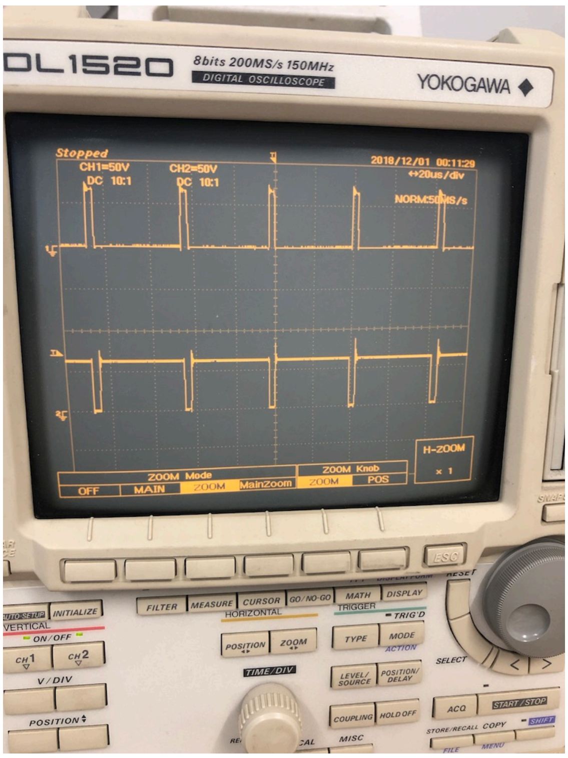


Fig. 47 Dead time of MOSFET

3.3. Brief economic evaluation

The realization of this circuit to make the inverter work is certainly advantaged by the low cost of the components necessary for its correct operation. In fact, to achieve everything you can spend at best no more than about € 20.00, up to an expense that can triple depending on where you buy the card and the components of the circuit. In fact, the EGS002 card can cost around € 6,00 to € 10, the remaining costs are for the purchase of the components needed to build the circuit.

3.4. Conclusions

This board, as we have guessed, is very versatile and allows the realization of a sinusoidal single-phase inverter at low cost. Following these tests, it was possible to ascertain how it is possible to regulate the amplitude of the voltage on the load, obtaining better results with the bipolar modulation rather than the unipolar one. Unfortunately, the bipolar configuration does not allow frequency adjustment. Moreover, it is possible to vary the dead time of the MOSFETs, obtaining an optimal operation for a constant frequency equal to 50Hz. Furthermore, the board allows, through a switch of appropriate ports, to choose the operation at 50Hz or 60Hz, so that it can also be used in countries with different electrical standards. It was found that after adjusting the board it was possible to adjust the frequency. This regulation, however, as can be guessed, requires an intervention on the main chip in order to make some pins of the chip suitable for performing the desired function. This definitely emphasizes how you need to pay attention in the various tests in order not to damage the board as well as the other components. In fact, during the numerous tests carried out, numerous damages to the boards occurred. Fortunately, there were many cards in the laboratory, 6 given the low cost, and this allowed to continue to work safely as well as it was possible to repair some. In fact, thanks to the documentation provided by the manufacturer it was possible to trace the problem, carrying out tests suggested by the manufacturer, so as to be able to trace the damaged components and replace them.

Finally, it is possible to interface with the card via a serial connection so as to perform a remote control of the functions whose experimentation could be the subject of future studies. The enormous advantage of this card in addition to its versatility is linked to the low cost that makes it highly competitive compared to many other products.

This card, given its versatility can be used for multiple purposes:

- Single-phase sinusoidal inverter;
- Inverter for solar energy production;
- Inverter for the production of wind energy;
- UPS (Uninterruptible power supply);
- Digital generator;
- Medium frequency power supply;
- Single-phase motor speed regulator;
- Single-phase frequency transformer;
- Sinusoidal light modulator;
- Sinusoidal voltage regulator;
- Sinusoidal generator;
- Inverter for solar production in isolated operation from the grid;
- Inverter welder.

Sitography

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